a scout scan. Each column, for example column **54** shown in FIG. **4**, represents data obtained simultaneously by different detector elements **20** of detector array **18**. FIG. **6** represents a plot of intensity data received for a column in a first scout scan as a function of detector element position in the column. (Arrow A is shown in FIGS. **6**, **7**, and **8** to provide a directional reference with respect to FIG. **4**. However, it should not be assumed that FIGS. **6**, **7**, and **8** are necessarily representative of the image shown in FIG. **4**, nor should it be assumed that FIGS. **6**, **7**, and **8** are drawn to the same scale.) Although cardiac calcification data is present in FIG. **6**, a calcification signal is not immediately evident. FIG. **7** shows a similar plot of a column in a second scout scan of patient **22** containing data representative of the same physical positions of patient **22**, but at a different phase of the cardiac cycle of heart **58**. An example of differences between two column signals such as those of FIG. **6** and FIG. **7** is plotted in FIG. **8**. Because the body of patient **22** is essentially motionless except for beating heart **58** (disregarding motion of table **46**), overlaying, non-moving body structures of patient **22** are removed by computing differences between the two scout images. As a result, the signals shown in FIG. **8** represent essentially only moving heart **58**. Because calcification signals are stronger than those of soft tissue and because calcification deposits move with heart **58**, signals from calcification deposits such as peak **74** are very apparent. Thus, when a difference image is determined between the two images that include the columns represented in FIGS. **6** and **7**, peaks such as peak **74** are easily seen. Peak **74** is thus readily identified as a calcification deposit on a portions of the image corresponding to a moving body structures of patient **22**. In one embodiment, computer **36** computes difference images and displays the computed difference images on CRT display **42**. Calcification scoring is readily accomplished using these computed difference images, either manually using an image on CRT display **42** or automatically, using image processing techniques.

In one embodiment, image processing techniques are used by computer **36** to further isolate, identify, and score calcification peaks such as peak **74**. For example, intensities of small groups of pixels **76** of a difference image **78** shown in part in FIG. **9** are compared to intensities of neighboring small groups of pixels **80**, where a "small group of pixels" refers either to one pixel or a few pixels in a cluster. When a difference is determined to be greater than a predetermined threshold indicative of calcification, sites represented by pixels **76** are identified as calcification sites for further study. In one embodiment, results of the intensity comparison are used directly for scoring an amount of calcification in accordance with differences in image intensities. The scoring results are used as a guideline for further examination.

In one embodiment, a difference image is enhanced by image processing to enhance the appearance of calcification **74** utilizing, for example, contrast enhancement algorithms. Differencing or other image processing procedures needed for contrast enhancement are implemented, for example, in hardware, software, or firmware of image reconstructor **34** or computer **36**, or both. In one embodiment, computer **36** is programmed both to display a difference image on CRT **42** and to automatically recognize and score calcification **74** by analysis of the difference image.

In one embodiment, scans of the two scout images are triggered by EKG signal **64** from EKG machine **50**. The EKG signal is supplied to computer **36**, which controls scanning and acquisition of image data in CT imaging system **10**. Computer **36** ensures that the two scout images taken are images of the same region of the body of patient **22** by controlling movement of table **46**. Computer **36** also ensures that the heart is in a different cardiac phase by starting the scans at different points in a cardiac cycle.

In an embodiment in which CT imaging system **10** is a multi-slice imaging system having more than one row of detector elements **20**, similar procedures for movement of table **46** are followed. However, a plurality of difference images are obtained, one for each row of detector **18**.

In another embodiment, multiple detector rows of a detector **16** in a multi-slice CT imaging system **10** are used in a single pass to generate a difference image. Computer **36** adjusts a rate of movement of table **46** during acquisition of data so that a small time lag occurs between acquisition of image data of the same body portions patient **22** by different rows of detector array **18**. Computer **36** selects an amount of time lag in accordance with a heart rate of patient **22** determined, for example, from EKG signal **64**. The amount of time lag is selected to ensure that image data is acquired by different rows of detector **18** during different portions of a cardiac cycle. In this manner, image data acquired from two different rows of a multi-slice detector **18** obtained during a single pass of a scout scan is used to obtain two suitable scout images. A difference image for scoring is computed from those portions of the two scout images that include at least a portion of heart **58** and that represent the same physical locations of the body of patient **22**. Portions of each image acquired by the two rows of detector **18** that do not overlap are simply ignored.

In another embodiment utilizing a multi-slice CT imaging system **10** having more than two rows of detectors, additional information for estimating background noise in obtained. For example, three or more rows of detectors obtain three or more scout images, including two for computing a difference image, and noise estimation information including at least a third scout image. Background noise in the difference image is estimated and reduced utilizing the noise estimation information and standard signal processing techniques.

From the preceding description of various embodiments of the present invention, it is evident that the problem of motion-induced artifacts in CT imaging systems is overcome, especially for calcification scoring purposes. Moreover, by reducing or eliminating non-moving body parts in a difference image, scoring of calcification is readily accomplished, even though only small incremental x-ray attenuation is produced by calcification.

Although particular embodiments of the invention have been described and illustrated in detail, it is to be clearly understood that the same is intended by way of illustration and example only and is not to be taken by way of limitation. Accordingly, the spirit and scope of the invention are to be limited only by the terms of the appended claims and legal equivalents.

What is claimed is:

1. A method for producing CT images of a patient's heart suitable for calcification scoring, the heart having a cardiac cycle;

said method comprising the steps of:

acquiring data representative of a first scout-scanned CT image of physical locations of the patient's body including at least a portion of the patient's heart at phases $\phi_1(L)$ of the cardiac cycle;

acquiring data representative of a second scout-scanned CT image of the physical locations of the patient's body including at least a portion of the patient's heart at phases $\phi_2(L)$ of the cardiac cycle different from $\phi_1(L)$; and

determining a difference image from the acquired data representative of the first scout-scanned CT image and the acquired data representative of the second scout-scanned CT image data.

2. A method in accordance with claim 1 wherein the patient is holding his or her breath during both said image acquiring steps.

3. A method in accordance with claim 1 further comprising the step of identifying calcification deposits on portions of the difference image corresponding to moving body structures of the patient.

4. A method in accordance with claim 3 wherein said step of identifying calcification deposits is performed utilizing computer image processing.

5. A method in accordance with claim 3 wherein identifying calcification deposits on portions of the difference image corresponding to moving body structures of the patient comprises comparing intensities of neighboring pixel groups of the difference image to identify differences in intensity above a threshold indicative of calcification.

6. A method in accordance with claim 5 wherein identifying calcification deposits further comprises scoring an amount of calcification in accordance with differences in image intensities.

7. A method in accordance with claim 1 further comprising the step of processing the difference image to enhance appearance of calcification deposits.

8. A method in accordance with claim 1 further comprising the step of monitoring an EKG signal of the patient's heart to determine trigger times for acquiring the data representative of the first image and the data representative of the second image at different phases of the cardiac cycle.

9. A method in accordance with claim 1 wherein both steps of acquiring data are performed at the same time utilizing different detector rows of a multi-slice CT imaging system.

10. A method in accordance with claim 9 wherein the CT imaging system comprises a table configured to move the patient during a scout scan, and further comprising the step of adjusting a rate at which the table moves during said data acquiring steps in accordance with a heart rate of the patient.

11. A method in accordance with claim 10 wherein the multi-slice CT imaging system comprises at least three detector rows, and said method further comprises the steps of acquiring noise estimation information including data representative of a third scout-scanned image, and estimating background noise in the difference image utilizing the noise estimation information.

12. A CT imaging system for obtaining images of a patient's heart suitable for calcification scoring, the heart having a cardiac cycle;

said system configured to:

acquire data representative of a first scout-scanned CT image of physical locations of the patient's body including at least a portion of the patient's heart at phases $\phi_1(L)$ of the cardiac cycle;

acquire data representative of a second scout-scanned CT image of the physical locations of the patient's body including at least a portion of the patient's heart at phases $\phi_2(L)$ of the cardiac cycle different from $\phi_1(L)$; and

determine a difference image from the acquired data representative of the first scout-scanned CT image and the acquired data representative of the second scout scanned CT image data.

13. A system in accordance with claim 12 further configured to identify calcification deposits on portions of the difference image corresponding to moving body structures of the patient.

14. A system in accordance with claim 13 configured to identify calcification deposits utilizing computer image processing.

15. A system in accordance with claim 13 wherein said system being configured to identify calcification deposits on portions of the difference image corresponding to moving body structures of the patient comprises said system being configured to compare intensities of neighboring pixel groups of the difference image to identify differences in intensity above a threshold indicative of calcification.

16. A system in accordance with claim 15 wherein said system being configured to identify calcification deposits further comprises said system being configured to score an amount of calcification in accordance with differences in image intensities.

17. A system in accordance with claim 12 further configured to process the difference image to enhance appearance of calcification deposits.

18. A system in accordance with claim 12 further configured to monitor an EKG signal of the patient's heart to determine trigger times for acquiring the data representative of the first image and the data representative of the second image at different phases of the cardiac cycle.

19. A system in accordance with claim 12 having a multi-slice detector, said system being configured to acquire both the data representative of the first image and the data representative of the second image at the same time utilizing different detector rows of said multi-slice detector.

20. A system in accordance with claim 19 further comprising a table configured to move the patient during a scout scan, and further configured to adjust a rate at which the table moves during scout-scanned data acquisition in accordance with a heart rate of the patient.

21. A system in accordance with claim 20 wherein said multi-slice detector comprises at least three detector rows, and said system is further configured to acquire noise estimation information including data representative of a third scout-scanned image, and to estimate background noise in the difference image utilizing the noise estimation information.

* * * * *